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ACTIVE AND PASSIVE REMOTE SENSING OF ICE(U)
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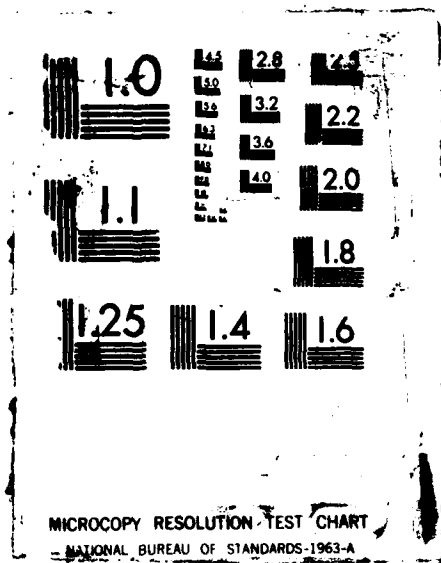
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ACTIVE AND PASSIVE REMOTE SENSING OF ICE

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SEMI-ANNUAL REPORT

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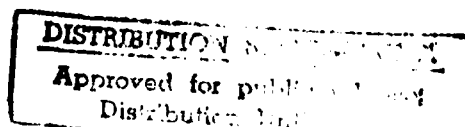
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ACTIVE AND PASSIVE REMOTE SENSING OF ICE

Principal Investigator: Jin Au Kong

SEMI-ANNUAL PROGRESS REPORT

Under the sponsorship of the ONR contract N00014-83-K-0258, we have published 2 books, 41 journal and conference papers and 10 student theses.

A systematic approach for the identification of terrain media is developed using the optimum polarimetric classifier. The covariance matrices for various terrain cover are computed from theoretical models of random medium by evaluating the full polarimetric scattering matrix elements. The optimal classification scheme makes use of a quadratic distance measure and is currently applied to classify a vegetation canopy consisting of both trees and grass. Experimentally measured data are used to validate the classification scheme. Theoretical probability of classification error using the full polarimetric matrix is compared with classification based on single features which include the phase difference between the VV and HH polarization returns. It is shown that the full polarimetric results are optimal and provide better classification performance than single feature measurements. The application of this classification scheme to sea ice will be explored.

> We have studied the volume scattering effects of snow-covered sea ice with a three-layer random medium model for microwave remote sensing. The strong fluctuation theory and the bilocal approximation are applied to calculate the effective permittivities for snow and sea ice. The wave scattering theory, in conjunction with the distorted Born approximation, is then used to compute bistatic coefficients and backscattering cross sections. Theoretical results are illustrated by matching experimental data for dry snow-covered thick first-year sea ice at Point Barrow. The radar backscattering cross sections are seen to increase with snow cover for snow-covered sea ice, due to the increased scattering effects in the snow layer. The results derived can also be applied to the passive remote sensing by calculating the emissivity from the bistatic scattering coefficients.



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We have also derived a general mixing formula for discrete scatterers immersed in a host medium. The inclusion particles are assumed to be ellipsoidal. The electric field inside the scatterers is determined by quasistatic analysis, assuming the diameter of the inclusion particles to be much smaller than the wavelength. The results are applicable to general multiphase mixtures, and the scattering ellipsoids of the different phases can have different sizes and arbitrary ellipticity distribution and axis orientation, i.e., the mixture may be isotropic or anisotropic. The resulting mixing formula is nonlinear and implicit for the effective complex dielectric constant, because the approach in calculating the internal field of scatterers is self-consistent. Still, the form is especially suitable for iterative solution. The formula contains a quantity called the apparent permittivity, and with different choices of this quantity, the result leads to the generalized Lorentz - Lorenz formula, the generalized Polder - van Santen formula, and the generalized coherent potential - quasicrystalline approximation formula. Finally, the results are applied to calculating the complex effective permittivity of snow and sea ice.

The Mueller matrix and polarization covariance matrix are described for polarimetric radar systems. The clutter is modelled by a layer of random permittivity, described by a three-dimensional correlation function, with variance, and horizontal and vertical correlation lengths. This model is applied, using the wave theory with Born approximations carried to the second order, to find the backscattering elements of the polarimetric matrices. It is found that 8 out of 16 elements of the Mueller matrix are identically zero, corresponding to a covariance matrix with four zero elements. Theoretical predictions are matched with experimental data for vegetation fields.

The study of the strong fluctuation theory for a bounded layer of random discrete scatterers, are extended to include high-order co-polarized and cross-polarized second moments. The backscattering cross sections per unit area are calculated by including the mutual coherence of the fields due to the coincidental ray paths and that due to the opposite ray paths which are corresponding to the ladder and cross terms in the Feynman diagrammatic representation. It is proved that the contributions from ladder and cross terms for co-polarized backscattering cross sections are the same, while the contributions for the cross-polarized ones are of the same order. The bistatic scattering coefficients in the second-order approximation for both the ladder and cross terms are also obtained. The

enhancement in the backscattering direction can be attributed to the contributions from the cross terms.

→ We have derived the dyadic Green's function for a two-layer anisotropic medium. The Born approximation is used to calculate the scattered fields. With a specified correlation function for the randomness of the dielectric constant, the backscattering cross sections are evaluated. The analytic expressions for backscattering coefficients are shown to include depolarization effects in the single-scattering approximation. It is also shown that the backscattering cross section (per unit area) of horizontal polarization can be greater than that of vertical polarization even in the case of half-space. The bistatic scattering coefficients are first calculated and then integrated over the upper hemisphere to be subtracted from unity, in order to obtain the emissivity. The principle of reciprocity is then invoked to calculate the brightness temperatures. It is shown that both the absorptive and randomly fluctuating properties of the anisotropic medium affect the behavior of the resulting brightness temperatures both in theory and in actual controlled field measurements. The active and passive results are favorably matched with the experimental data obtained from the first-year and the multiyear sea ice as well as from the corn stalks with detailed ground-truth information.

Electromagnetic wave propagation and scattering in an anisotropic random medium ^{has been} examined with Dyson equation for the mean field, ^{which} is solved by bilocal and nonlinear approximations and with Bethe-Salpeter equation for the correlation of field, ^{was} derived and solved by ladder approximation. The effective propagation constants are calculated for the four characteristic waves associated with the coherent vector fields propagating in an anisotropic random medium layer, which are the ordinary and extraordinary waves with upward and downward propagating vectors. The z-component of the effective propagation constant of the upward propagating wave is different from the negative of that of the downward propagating wave, not only for the extraordinary wave but also for the ordinary wave. This is due to the tilting of the optic axis which destroys the azimuthal symmetry.

Since both snow and ice exhibit volume scattering effects, we model the snow-covered ice fields by a three-layer random medium model with an isotropic layer to simulate snow, an anisotropic layer to simulate ice, and the bottom one being ground or water. The snow and ice are characterized by different dielectric constants and correlation functions. The theoretical results are illustrated for thick first-year sea ice covered by dry snow at Point Barrow and for artificial thin first-year sea ice covered by wet snow at CRREL. The radar backscattering cross sections are seen to increase with snow cover for snow-covered sea ice, because snow gives more scattering than ice. The results are also used to interpret experimental data obtained from field measurements.

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